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The transmission of an acoustic wave through a rectangular plate between barriers☆

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ABSTRACT

The problem of the forced vibrations of a rectangular elastic plate hinged to the sides of an opening in an absolutely stiff partition upon the transmission of a monoharmonic acoustic wave through it is considered. It is assumed that the partition is located between two absolutely stiff barriers, one of which forms an acoustic wave that is incident to the plate due to harmonic vibrations with an assigned displacement amplitude, while the other barrier is fixed and has a deformable energy-absorbing coating made from a material with high damping properties. The behaviour of acoustic media in spaces between a deformable plate and barriers is described by classical wave equations based on the model of an ideal compressible fluid, and the mechanics of the deformation of the plate are described by the equations of motion from the classical linear plate theory with consideration of the internal friction of the plate material according to the Thompson–Kelvin–Voigt hysteretic model. To describe the process of the dynamic deformation of an energy-absorbing coating on a fixed barrier, two-dimensional equations of motion based on the use of a model of a transversely soft layer, a linear approximation of the displacement fields in the direction of the thickness of the coating and consideration of the damping properties of its material also according to the hysteretic model are derived. Analytical solutions of the problem are found with and without consideration of the compliance of the supporting elements of the plate. The influence of the physicomechanical parameters of the mechanical system under consideration on the sound reduction parameters of the plate and the sound pressure in the spaces between the plate and the barriers, as well as of the stress-strain state under forced vibrations of the plate as a function of the frequency of the acoustic wave incident to it, is investigated. It is shown that the mechanical behaviour of the plate in the vicinity of resonance frequencies depends practically completely on the aerodynamic damping and that for stiff building materials, which have, as a rule, small values of the logarithmic decrement of the vibrations, taking into account the internal damping has an insignificant influence on the parameters investigated of the system.

In the second half of the preceding century, a field of science associated with the investigation of the steady and unsteady interaction of acoustic waves with barriers in the form of deformable solid bodies and thin-walled structural elements was created. This field continues to attract the attention of researchers because of its timeliness, complexity and the large variety of phenomena inherent in the process of the interaction of bodies of different physical nature. Issues in aerohydroelasticity of thin-walled shell-like structures related to this field have been elucidated in numerous monographs and reviews (Refs 1–4 and so on). However, issues in formation of acoustic waves and the investigation of the problems concerning sound reduction and sound absorption by certain deformable barriers are not considered in them, although it has been pointed out in practically all the publications devoted to the creation of diverse multilayer structures that they have good sound reduction and sound absorption properties (Refs 5, 6 and so forth). Such problems of mechanics are classified as problems of acoustoelasticity, which have been the subject of fairly extensive literature in the form of scientific articles (Refs 7–10 and so forth), monographs (Refs 11–13) and review articles (Refs 14–18 and so forth).

The subject of this article is the problem of the forced vibrations of a rectangular elastic plate hinged to the sides of an opening in an absolutely stiff partition when a monoharmonic external pressure acts on it. Investigations of the forced vibrations of thin-wall structural

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